Internal thoracic artery harvesting without pleurotomy – does smaller injury mean a better outcome?

Pobranie tętnicy piersiowej wewnętrznej bez pleurotomii – czy mniejszy uraz jest jednoznaczny z lepszymi wynikami operacyjnymi?

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Abstract

Introduction: The internal thoracic artery (ITA) remains the graft of choice for coronary artery bypass grafting (CABG). Harvesting the ITA without pleurotomy may be a desirable approach if the technique is proven to decrease morbidity and mortality and improve the economic result. The aim of the study was to evaluate the impact of different harvesting techniques on postoperative blood loss, transfusion requirements and duration of postoperative therapy.
Material and methods: We carried out a prospective study that involved 115 patients who underwent on-pump CABG in our clinic. Patients were divided into two groups: those who underwent pleurotomy due to ITA harvesting (group A; $n = 73$) and the rest where pleura spearing technique was applied (group B; $n = 42$). Predicting factors for proposed end-points were assessed by stepwise forward regression.
Results: Postoperative chest tube drainage (CTD) at the 12th and the 24th hour as well as the hemoglobin level did not differ statistically. Nonetheless, patients with pleurotomy required significantly more units of packed red blood cells (RBC), fresh frozen plasma (FFP) and packed platelets (PLT) than patients with intact pleural cavity (RBC = 0.94 ±1.4 vs. 0.5 ±0.9; $p < 0.001$; FFP = 0.6 ±1.5 vs. 0.4 ±1.1; $p < 0.001$; PLT = 0.3 ±1.5 vs. 0.1 ±0.8; $p < 0.001$). Regression analysis indicated that opening of the pleural cavity was a prediction factor for higher CTD at the 12th hour ($\beta = 0.18$; $p = 0.03$) and prolonged postoperative hospitalization ($\beta = 0.17$; $p = 0.04$). Group A patients were also found to require a longer intensive care unit (ICU) stay than those of group B (A: 1.5 ±1.0 vs. B: 1.3 ±0.6; $p < 0.001$).
Conclusion: Spearing of pleura in the ITA harvesting procedure decreases morbidity and improves the economic result for patients qualified for on-pump CABG.

Streszczenie

Wstęp: Lewa tętnica piersiowa wewnętrzna utrzymuje pozycję niekwestionowanego lidera wśród naczyń stosowanych w pomostowaniu aortalno-wieńcowym (ang. *coronary artery bypass graft* – CABG). Pobieranie tętnic piersiowych bez naruszania ciągłości jam opłucnowych może stanowić pożądane podejście chirurgiczne, jeżeli metoda ta wpłynie korzystnie na długość przeżycia, zachorowalność i aspekt ekonomiczny chirurgii wieńcowej.
Cel pracy: Celem badania była ocena wpływu techniki pobierania tętnicy piersiowej wewnętrznej na okołooperacyjną utratę krwi, zapotrzebowanie na transfuzję produktów krwiopochodnych oraz czas trwania poszczególnych etapów hospitalizacji.
Materiał i metody: Do badania zakwalifikowano w sposób prospektywny 115 pacjentów, którzy zostali poddani zabiegowi CABG w Klinice Chirurgii Serca Akademii Medycznej we Wrocławiu. Pacjenci zostali losowo zakwalifikowani do dwóch grup. Grupa A ($n = 73$) składała się z pacjentów, u których zastosowano szerokie otwarcie jamy opłucnowej w procesie pobierania lewej tętnicy piersiowej wewnętrznej; w grupie B ($n = 42$) zastosowano technikę polegającą na zachowaniu ciągłości opłucnej. Porównano przebieg okołooperacyjny pacjentów alokowanych do obydwu grup pod względem okołooperacyjnej utraty krwi, ilości przetoczeń preparatów krwiopochodnych oraz czasu trwania hospitalizacji na poszczególnych etapach leczenia.
Wyniki: Objętość drenażu pooperacyjnego w 12. i 24. godzinie oraz poziom pooperacyjny hemoglobiny nie osiągnęły różnicy istotnej statystycznie. Tym niemniej pacjenci w grupie, w której wykonywano pleurotomię, wymagali istotnie więcej transfuzji koncentratów krwinek czerwonych, świeżo mrożonego osocza oraz koncentratów krwinek płytkowych niż pacjenci

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z zamkniętą jamą opłucnową (RBC = 0,94 ±1,4 *vs* 0,5 ±0,9; p < 0,001; FFP = 0,6 ±1,5 *vs* 0,4 ±1,1; p < 0,001; PPT = 0,3 ±1,5 *vs* 0,1 ±0,8; p < 0,001). Analiza modelu regresji krokowej postępującej wskazuje, iż otwarcie jamy opłucnowej stanowiło czynnik ryzyka zwiększonej objętości drenażu w 12. godzinie po zabiegu (β = 0,18; p = 0,03) oraz przedłużonego czasu hospitalizacji (β = 0,17; p = 0,04). Pacjenci z otwartą jamą opłucnową wymagali ponadto istotnie dłuższego pooperacyjnego pobytu na oddziale intensywnej terapii niż pozostała grupa leczonych (A: 1,5 ±1,0 *vs* B: 1,3 ±0,6; p < 0,001).

Wnioski: Zachowanie ciągłości opłucnej ściennej podczas zabiegu pobierania tętnicy piersiowej wewnętrznej skraca czas trwania hospitalizacji, zmniejsza zakres powikłań krwotocznych, przyczyniając się tym do redukcji kosztów chirurgicznego leczenia zaawansowanej choroby wieńcowej.

Słowa kluczowe: pomostowanie aortalno-wieńcowe, lewa tętnica piersiowa wewnętrzna, pleurotomia, przeszczepianie tętnic klatki piersiowej, krwawienie, powikłania pooperacyjne.

Introduction

According to the 2010 Annual Report of the Polish Heart Surgeons' KROK Database, there were 13 285 isolated coronary artery bypass grafting (CABG) procedures in Poland in 2009 [1]. Owing to its anatomical availability, long standing patency and tremendous clinical outcome when used as a graft for coronary bypass surgery, the left internal thoracic artery (LITA) serves as a gold standard in the surgical treatment of coronary artery disease (CAD) [2]. It is not surprising that many nuances emerged according to operative technique leading to a successful takedown of the vessel. Noera et al. demonstrated that pleurotomy during LITA harvest has a negative impact not only on lung function, but also on the blood loss measured as red blood cell (RBC) units transfused postoperatively [3]. No evidence was given as far as other blood product requirements are concerned. Length of intensive care unit (ICU) stay and overall hospitalization time have been analyzed in this setting, although the evidence on this subject seems vague [4-8]. By far the most clear evidence was gathered on the superiority of lung function in patients with intact pleura over opening of the pleural cavity [4-8]. The aim of our study was to assess the utility of the extrapleural LITA harvesting technique, by means of blood loss, transfusion rates, pulmonary function assessment and in-hospital therapy duration. This was achieved by the comparison of post-operative outcome of patients with open pleural cavity and those whose pleura remained intact.

Aim of study

The present study compared two LITA harvesting techniques, with or without opening of the pleural cavity, in terms of their genuine safeness and postoperative outcome measured as postoperative blood loss, transfusion requirements, pulmonary complications and duration of hospital stay.

Material and methods

Our study was conducted in a prospective manner. Randomization was achieved by random allocation of patients to one of the two operating rooms (ORs) at our faculty (Microsoft Excel 2007, Microsoft Inc.): OR 1, where intact pleura technique was undertaken; and OR 2, where standard technique was implemented. The study group consisted of 115 patients hospitalized in our faculty between January 2007 and December 2008. The inclusion criteria were as follows: elective surgery, isolated coronary artery disease (CAD), no previous cardiac surgery, no previous percutaneous coronary intervention (PCI), negative history of chronic or acute pulmonary diseases, coagulopathy, major adverse cerebro-vascular accidents, diabetes, chronic kidney disease or malignancy. Patients requiring emergency surgery or suffering from significant left main stenosis as well as those requiring intra-aortic balloon pump (IABP) both pre- and postoperatively were excluded from the study. In all subjects antiplatelet therapy was withdrawn in a safe interval of five days before the surgery.

Demographic structure, and medical history were analyzed beforehand. Typical parameters of hemostasis and postoperative bleeding were recorded at different stages of the postoperative period. Postoperative blood product requirements were assessed as the unit of blood product required per patient. The duration of overall hospital and the ICU stay were analyzed as the difference in average time spent in the ICU and in the cardiac surgery ward until hospital discharge. The postoperative pulmonary function was measured as the time needed to wean from the mechanical ventilatory support (orotracheal intubation time – ORT). All postoperative complications were recorded and analyzed.

A total of 115 patients were divided into two groups. In group A (n = 73) a standard LITA harvesting technique was used. The surgical technique consisted of wide opening of the pleural cavity in order to achieve the best visualization and the most surgeon friendly environment. In this setting the LITA was taken down as a pedicle with surrounding tissue, e.g. endothoracic fascia, internal thoracic veins and surrounding adipose tissue. Group B (*n* = 42) consisted of patients in whom extrapleural LITA harvesting technique was applied; hence no pleural cavity was opened. In this case, the LITA was harvested in a semi-pedicled manner, e.g. artery surrounded by two internal thoracic veins and encircling adipose tissue but without the endothoracic fascia. All patients were operated on by a single cardiac surgeon (R.N.) In all cases harvesting of the LITA was performed using bipolar electrocautery (Force FX™, Valleylab, Colorado, USA). All side branches were ligated with hemaclips.

Surgical protocol

The routine on-pump CABG protocol of our clinic was applied to all patients. Premedication was admitted one hour before the operation with morphine 0.1 mg/kg and midazolam 7.5 mg orally. Anesthesia was induced with propofol TCI 2-4 µg/ml and fentanyl 5-7.5 µg/kg. Intubation was facilitated with pancuronium 0.1 mg/kg. To maintain anesthesia propofol TCI 2-3 µg/ml and fentanyl 5-10 µg/kg/h as a continuous intravenous infusion was used. Ventilation was controlled artificially with a mixture of air and oxygen (initially FiO_2 of 1.0 and 0.6 thereafter). All patients underwent surgical revascularization by a standard median sternotomy. All patients were supported by a cardiopulmonary bypass with non-pulsatile flow (2.2-2.4 l/min/m^2) using a Dideco Compacflo ECC device when arrested. Warm blood cardioplegia protection was administered antegrade according to the Calafiore protocol in normothermia. Activated clotting time (ACT) was maintained between 100 and 120 seconds shortly after cardiopulmonary bypass termination. All patients were given tranexamic acid i.v. 1.0 g preoperatively and 1.0 g shortly before leaving the OR. This protocol was implemented in all patients regardless of their coagulation status.

Tab. I. Preoperative baseline variables

	Group A (*n* = 73)	Group B (*n* = 42)	*p*
Age	66.3 ±8.9	63.7 ±9.0	NS
Sex	W: 19, M: 54	W: 7, M: 35	NS
Body mass index	28.1 ±4.7	28.7 ±5.5	NS
LVEF [%]	57.1 ±10.9	58.6 ±9.0	0.047
aPTT [s.]	32.0 ±6.5	31.8 ±3.7	NS
INR	1.04 ±0.06	1.06 ±0.09	NS
HGB [mg%]	13.9 ±1.4	14.2 ±1.7	NS
PLT [x10^3]	211.2 ±61.7	217.9 ±58.9	NS

LVEF – left ventricular ejection fraction, aPTT – partial thromboplastin time, INR – international normalized ratio, HGB – hemoglobin, PLT – platelets.

Tab. II. Operative outcome

	Group 1 (*n* = 73)	Group 2 (*n* = 42)	*p*
No. of SV grafts	1.68 ±0.7	1.7 ±0.7	NS
No. of LITA grafts	73 (100%)	42 (100%)	NS
No. of RA grafts	1 (1.4%)	0 (0%)	NS
CPB time [min]	68.2 ±30.4	71.0 ±30.4	NS
Aorta cross clamp time [min]	31.04 ±15.13	33.6 ±14.8	NS
Inotropic support during bypass weaning [pts]	18 (24.7%)	8 (19.5%)	NS

SV – saphenous vein, LITA – left internal thoracic artery, RA – radial artery, CPB – cardiopulmonary bypass.

Statistical analysis

The study was approved by the Institutional Review Committee. The statistical analysis was performed with the aid of Statistica 9.0 software, StatSoft Inc. Before any further analysis all data were tested for normal distribution by Shapiro-Wilk test and Leven test for variance homogeneity. Results were displayed as mean and standard deviation. The Student T-test, Wald-Wolfowitz and Chi-squared tests were applied for univariate analysis. Stepwise forward regression was used to reveal the prediction factors of studied end-points. Statistical significance was assumed at $p < 0.05$.

Results

The two groups did not differ as far as demographic data and preoperative morbidity are concerned. There was an inequality in left ventricular ejection fraction (LVEF) between groups, in favor of group B (58.6 ±9.0 vs. 57.1 ±10.9; $p = 0.047$). No differences were found as far as preoperative parameters of hemostasis are concerned. Average number of neither arterial nor venous grafts differed between groups. All patients had comparable time of aorta cross-clamp, cardiopulmonary bypass (CPB) time, and requirements for inotropic support intraoperatively (Tab. I and Tab. II).

Although one patient in each group suffered cardiac arrest, there was no in-hospital mortality in either group. There was one major coronary and one cerebral adverse event, both in group A, which consisted of perioperative myocardial infarction (CKMB > 10% of total CK, new q waves and loss of R forces over an anatomical region of the lateral aspect of the anterior wall) and stroke. This did not reach statistical significance. No development of chronic or acute kidney disease was observed (Tab. III).

Blood loss

Neither 12 nor 24 hour chest tube drainage differed significantly between groups, although in group A it was higher by approximately 70 ml per patient. No significant difference in postoperative level of hemoglobin was noted,

Tab. III. Postoperative complications (in-hospital follow-up)

	Group 1 (*n* = 73)	Group 2 (*n* = 42)	*p*
Major adverse cerebral events	1 (1.4%)	0 (0%)	NS
Perioperative myocardial infarction	1 (1.4%)	0 (0%)	NS
Cardiac arrest (all in VF mechanism)	1 (1.4%)	1 (2.4%)	NS

VF – ventricular fibrillation.

even though patients of group A required reoperation for bleeding five times more often than those of group B. As shown by stepwise forward regression for both groups, the factors having the most significant impact on CTD at 12 hours after the surgery were as follows: preoperative partial thromboplastin time (aPTT) (β = 0.39; p < 0.001), international normalized ratio (INR) (β = 0.51; p = 0.001), preoperative platelet count (β = 0.17; p = 0.04) preoperative LVEF (β = –0.19; p = 0.02), age (β = –0.17; p = 0.04), aorta cross-clamp time (β = –0.17; p = 0.03), and, most importantly, opening of left pleural cavity while harvesting LITA (β = 0.18; p = 0.03). As for CTD 24 hours postoperatively the most significant factors were alike: preoperative aPTT (β = 0.56; p < 0.001), INR (β = 0.31; p = 0.04), postoperative INR (β = 0.45; p < 0.001), hemoglobin level 12 hours postoperatively (β = –0.21; p = 0.003), age (β = –0.26; p < 0.001) and female gender (β = –0.19; p < 0.001) (Tab. IV).

Blood product requirements

Patients of group A were found to require more blood products than those of group B. That concerned not only packed red blood cells, but also packed platelets, and fresh frozen plasma. We did not find any significant differences between the coagulation tests and the platelet count postoperatively (Tab. V).

Time of therapy, ICU stay and indirect assessment of pulmonary function

The time of ventilatory support, preoperative INR and LVEF on admission were the factors influencing the duration of postoperative ICU stay (respectively: β = 0.21; p = 0.02, β = 0.52; p = 0.002, β = –0.17; p = 0.03). The time spent on the ICU was significantly longer for those of group A, although overall time of hospital stay did not differ among the groups. Opening of the pleural cavity had a negative impact on the overall hospital stay (β = 0.17; p = 0.04), hence committing to prolonged hospitalization. The very same trends were observed for high body mass index (β = 0.25; p = 0.003) and advanced age (β = 0.26; p = 0.005), which were also strong predictors of prolonged hospital stay (Tab. VI).

Tab. IV. Postoperative blood loss

	Group 1 (n = 73)	Group 2 (n = 42)	p
CTD at 12th hour postoperatively [ml]	590.2 ±427.0	518.1 ±292.5	NS
CTD at 24th hour postoperatively [ml]	809.2 ±530.9	708.6 ±368.3	NS
Hemoglobin level postoperatively [mg%]	9.8 ±1.2	10.6 ±1.3	NS
Hemoglobin level 12 hours postoperatively [mg%]	9.6 ±1.4	10.3 ±1.4	NS
Reoperation for bleeding	5 (6.8%)	1 (2.4%)	NS

CTD – chest tube drainage.

Comments

Postoperative blood loss. Normothermic cardiopulmonary bypass is known to cause fewer coagulation derangements than the moderate hypothermic one, yet platelet mechanical activation, systemic inflammatory response caused by blood exposure to artificial materials, and unfractionated heparin use have long been the attributed disadvantages of on-pump CABG [9-12]. The operative technique should also be appreciated as an important factor limiting or aggravating the postoperative drainage capacity [3, 6, 10-12]. An extensive tissue resection while harvesting the LITA as a pedicle might contribute to the above statement as well. The literature has little or no evidence on how the postoperative blood loss impacts the postoperative transfusion requirements and causes the need for prolonged hospitalization in the ICU. Similarly to the existing body of evidence, we conclude that opening of the pleural cavity during LITA harvest is associated with more pronounced blood loss, a bigger drop in postoperative hemoglobin and higher rates of reoperation for bleeding [3, 6]. In our opinion insertion of even the softest chest tube into the pleural cavity might have the ability to cause mechanical irritation and consequently fluid secretion, which adds to the total drainage capacity. The pleural tube is also found to cause pulmonary function infringements and is associated with greater postoperative pain and higher need for opioid analgesia in the ICU [4].

Transfusion requirements. In comparison with other authors we have gone further in the analysis of perioperative blood product requirements [3, 6]. There is clear evidence that for every unit of packed red blood cells transfused in the intact pleural cavity group, two units were transfused in those with an opened pleural cavity. We hypothesize that higher rates of FFP and PLT transfused in patients with opened pleura did not have to be caused by greater coagulation derangements in this group. This might be due to the

Tab. V. Postoperative CBC and blood product requirements

	Group 1 (n = 73)	Group 2 (n = 42)	p
PLT [x10^3]	137.2 ±55.3	145.3 ±50.4	NS
aPTT [s.]	39.9 ±10.7	40.8 ±14.3	NS
INR	1.5 ±0.2	1.4 ±0.1	NS
Packed red blood cells (u.)	0.94 ±1.4	0.5 ±0.9	< 0.001
Fresh frozen plasma (u.)	0.6 ±1.5	0.4 ±1.1	< 0.001
Packed platelets (u.)	0.3 ±1.5	0.1 ±0.8	< 0.001

Tab. VI. Time of therapy and pulmonary complications.

	Group A (n = 73)	Group B (n = 42)	p
Time of ICU stay [days]	1.5 ±1.0	1.3 ±0.6	< 0.001
Time of hospitalization [days]	9.3 ±5.4	10.9 ±8.4	NS
Ventilatory support time [h]	8.2	8.2	NS
Prolonged intubation	0 (0%)	1 (2.4%)	NS
Reintubation	1 (1.4%)	0 (0%)	NS

additional space opened for fluid retention in the pleural cavity, which does not take place when the pleura remains closed. Residual bleeding that might be left behind, beyond the ability of the surgeon to be cauterized or ligated, may be stopped by the elements of the parietal pleura when it remains intact. This hemostatic quality of the pleura might be associated with its ability to close the free space, and adhere to fibrin coated surfaces.

Duration of therapy. There was a tendency in group A to require longer ICU stay. This, as we believe, has a multifactorial explanation. Not only postoperative bleeding but also pulmonary function deficits and worse preoperative LVEF were key factors in this setting. In contrast to other scientific statements on this issue, we did not find a significant difference in overall hospital stay [4, 6]. Yet, the fact of pleura being opened was found to be a strong predictive factor of prolonged hospitalization in all patients. That seems to be in agreement with aforementioned reports [4, 6].

Pulmonary function. Pulmonary complications in patients submitted to on-pump surgical revascularization are well documented. Taggart et al. attributed those complications to a systemic inflammatory response, which is well described in patients in whom cardiopulmonary bypass was used [13, 14]. As Bonnachi and colleagues have observed, this might serve as only a partial explanation [4]. Drugs usually considered in the anesthetic protocol such as pancuronium or opioid analgesics have a negative influence on perioperative ventilation by reducing the diaphragm and auxiliary respiratory muscle tone, and later by reducing chest compliance, and respiratory motor brain stem function. On the other hand, harvesting the LITA is by itself linked to worse pulmonary functioning after coronary surgery [14-16]. Opening of the pleural cavity is associated with higher rates of pleural effusion and atelectasis and by this fact alone should be linked to worse pulmonary status [3, 4, 6, 8]. All these factors together should be considered when describing post-CABG lung function. Our data seem to be in agreement with these findings.

Study limitations. We would like to acknowledge some of the study limitations. This study was modest in the number of patients. No objective pulmonary tests were conducted, and the intubation time might indeed be biased, and was in fact the most challenging protocol to control. At this point no follow-up has been conducted and no answer can be given as to how the intrusion of the pleural cavity might impact the short and the long term survival as well as other observed hard end-points.

Conclusions

Considering the above we conclude as follows:

Opening of the pleural cavity is associated with worse operative outcome in terms of post-operative blood product requirements, prolonged orotracheal intubation and longer hospitalization in the ICU. Before applying the open harvesting technique one should bear in mind that this is linked to a detrimental impact on pulmonary function and postoperative blood loss.

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